Chapter 27
Impacts of Chemical Use in Agricultural Practices: Perspectives of Soil Microorganisms and Vegetation

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Abstract Many plant and animal species have undergone extensive domestication as a result of ongoing agricultural intensification and extensive human sociocultural and economic development in a bid to improve global food production and security. However, the rise in consumption rate brought on by global population growth presents a constant and growing challenge. Therefore, many scientific and cutting-edge avenues are being explored to increase agricultural output and assured food security for everyone, especially in developing and underdeveloped parts of the world. These include the use of chemicals such as a broad class of pesticides - herbicides for weed and insect pest control as well as for greater yields and fertiliser applications for better crops and animal production. However, as the usage of these chemicals increased, so did their detrimental effects on soil microorganisms, above-ground flora, and other connected natural resources, and the quality of environmental matrices like soil, water, and air pollution. The types and classifications of agrochemicals, especially herbicides and fertilisers used in developing and underdeveloped countries exacerbate the effects, and impacts on soil microbes and vegetation. This chapter focuses on the issues related to the current realities of chemical application for agricultural productivity on above-ground flora and soil microorganisms and discusses potential sustainable management approaches.

Keywords Herbicides · Fertilisers · Agriculture · Vegetation · Soil microorganisms · Food security · Pollution

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Abbreviations

AMBA	2-amino-4-methylsulfonylbenzoic acid
BNF	Biological nitrogen fixation
C	Carbon
CHD	3-cyclohexanedione
CMBA	2-chloro-4-mesylbenzoic acid
CMP	1-carbamoyl-3-methyl pyrazole
CT	Conventional till
DAP	Diammonium phosphate
DH	Dehydrogenase
DMPP	3,4-dimethyl pyrazole phosphate
F1	First filial
GAP	Good agricultural practices
HRAC	Herbicides resistance action committee
IAA	Indoleatic acid
IPM	Integrated pest management
K	Potassium
MBC	Microbial biomass carbon
MES	Mesotrione
MNBA	4-methylsulfonyl-2-nitrobenzoic acid
MRL	Maximum residual limit
N	Nitrogen
NPK	Nitrogen phosphorus potassium
NT	No-till
OM	Organic matter
PCBs	Polychlorinated biphenyls
PHA	Phenylheptanoic acid
POPs	Persistent organic pollutants
PTSs	Persistent toxic substances
TEMB	Tembotrione
UAN	Urea ammonium nitrate
UF	Urea formaldehydes
WSSA	Weed Science Society of America

27.1 Introduction

Current agricultural techniques in many developing countries use unsustainable methods that have led to the direct or indirect release of a significant amount of hazardous effluents into the soil, air, and water (Yáñez et al. 2012). The situation of soil inputs and their degradation has become more complex as a result of the development of nanotechnology and nanomaterials (Mishra et al. 2017, 2018). It is

also very important to take into account the factor of variation in soil qualities depending on climatic and geographical variables (Marfo et al. 2019). Various agrochemicals, including herbicides, fungicides, insecticides, nematicides, molluscicides, rodenticides, and chemical fertilisers, are now being used carelessly, which has beneficial soil (micro) biota (Meena et al. 2016a, b).

A pesticide is any agent that is used to manage, deter, or eliminate plant or animal life. This category also includes fungicides, insecticides, and herbicides. Pesticide use is on the rise, and more than half of the pesticides used to come from Asia (Sonmez and Sonmez 2017). The exponential increase in the world's population has produced an urgent need for an ecologically sound plan to protect soil health and advance food security without destroying soil biodiversity on a worldwide level.

Pesticides play a key role in contemporary agricultural operations because of their effects on agronomic production and profit margin. However, herbicides used carelessly cause the microbial communities of soil to deteriorate. The primary decreasing biotic factors in agriculture are weeds and insects, which reduce agricultural production, productivity, and resource use effectiveness (Oliveira et al. 2014). To ensure increased productivity by eradicating or controlling pest populations, herbicides (a kind of pesticide that kills precisely targeted plants) and insecticides (a type of pesticide that kills specially targeted insects) are applied indiscriminately (Meena et al. 2016a, b). The top 10 nations in the world that use herbicides and insecticides are all topped by the United States. The use of pesticides is either widespread or prevalent over the globe because of the high cost of labour, the availability of chemical applications, and the promise of quick insect control (Bahadur et al. 2015). These chemical substances are either sprayed into the soil strata or applied directly, and as a result, drifting sprays, excessive inputs from leaching, and agricultural runoffs reach rivers, streams, and other bodies of water (Aktar et al. 2019).

As a result, the majority of complex agrochemical chemicals are applied to the soil, some of which are harmful to the activities of beneficial soil microorganisms that are not the intended targets (Wang et al. 2016). Since pesticides and herbicides are often sprayed uniformly over the whole field, even in healthy areas, a far higher percentage (sometimes more than 95%) of the chemical ultimately reaches soil microorganisms that are not the intended targets (Song et al. 2019; Ogwu et al. 2019). As a result, only around 1% of the total quantity of pesticides sprayed reaches the intended species, while the rest pollutes the soil and environment. Pesticides are being used carelessly, which disrupts not just the biodiversity of the soil but also the ecology and soil microfauna in field communities (Lo 2010; Ogwu et al. 2019; Ogwu 2019; Ikhajiagbe et al. 2021a, b, c, d, e). A biological indicator of soil fertility that influences plant growth and development, the soil microbiota is directly impacted by large amounts of pesticides reaching the soil (Santos and Flores 2015; Fabra et al. 2017; Hussain et al. 2019; Erinle et al. 2021). Similar to this, various studies have shown how different pesticides alter soil enzyme activity, including hydrolyses, nitrate reductase, urease, oxidoreductases, nitrogenase, and dehydrogenase activities. Pesticide applications also have an impact on biological nitrogen fixation (BNF) and the associated biotransformations (such as S-oxidation,

phosphorus solubilisation, nitrification, denitrification, and ammonification) (Monkiedje and Spiteller 2015; Wang et al. 2016).

Soil microorganisms mainly break down organic materials, but they also fix and mineralise other elements to provide nitrogen, phosphorus, potassium, and other elements. Hence assisting in the development of plants, the detoxification of dangerous chemicals, the suppression of disease-causing organisms, and the production of compounds that might promote plant growth (Bano and Iqbal 2016; Evivie et al. 2019). Additionally, soil bacteria create plant hormones that boost plant immune systems, promote development, and trigger stress responses in addition to mineralising the vital plant nutrients in the soil to increase crop output (Reitz et al. 2015). For instance, Rhizobium transforms the nitrogen element from the atmosphere into life. Soil health is influenced by factors that include population dynamics and biodiversity both above and below ground. Understanding the effects of agrochemicals on soil microbiota requires increased worldwide efforts and attention to management techniques for food supply and security, nutrition, health, and soil sustainability.

Therefore, this chapter aimed at discussing the impacts of chemical use in agricultural practices: perspectives of soil microorganisms and vegetation. It focuses on the issues related to the current realities of chemical application for agricultural productivity and their management and potential sustainable approaches.

27.2 Types and Classifications of Agrochemicals

27.2.1 Herbicides

Herbicides are chemicals used to kill or alter unwanted vegetation. Row-crop farming makes extensive use of herbicides, which are sprayed on either before or after planting to kill off unwanted plants and boost production. In the fall, they may be applied on crops to make for easier. iThe iside effects ion soil microorganisms and humans are detrimental and are heavily influenced by their toxic mode of action and application. Although the mechanisms of action are well established, the molecular location of action is difficult to predict since structural linkages have not been found (Duke 2013; Folmar et al. 2019). Due to their ability to mimic the effects of natural plant growth hormones, herbicides pose a risk of causing deformities via disruptions in cell division, photosynthesis, and amino acid production (Ross and Childs 2016). Spraying into foliage and applying to soil are two application techniques (Shepard et al. 2014).

27.2.1.1 Types of Herbicides

The many kinds of herbicides are all intended to destroy plant tissue. However, they carry it out using two fundamental strategies. They are referred to as Systemic and Contact Herbicides, respectively as shown in Table 27.1.

Herbicides that touch the plant will be killed by the chemical in that particular kind of herbicide; this is referred to as contact herbicides. This indicates that it will eradicate the leafy, above-ground portion of broadleaf weeds. It will not harm the portions of the plant that grow underground, such as the roots, bulbs, tubers, or rhizomes. Because they destroy the tissue in as little as 1 day, contact herbicides are well-liked because they are effective rapidly. For a quicker impact, some herbicides mix contact with systemic chemicals. For quicker management, both have been combined in the new Round Up Weed and Grass Killer. Others have followed suit. The above-ground parts of certain plants may not be sufficient to entirely eradicate them. The herbicide must be administered again since the majority of plants will regenerate plant tissue. But each time the plant expends energy to begin growing again, it becomes weaker and finally dies.

Herbicides classified as "systemic" are those that a plant absorbs via its leaves or stems and then distributes internally throughout the whole plant. Typically, the chemical doesn't have the immediate "knockdown" effect since it travels with the sap. The main advantage of a systemic herbicide is that it will destroy the plant, including the roots. The temperature of the soil and the air has a significant impact on how quickly chemicals flow throughout the plant. Early spring sprayings of chemicals may take a few weeks longer to take effect than mid-summer sprayings of the same chemicals. The "mode of action" of the chemical, or how the chemical operates within the plant, also affects how quickly an organism is killed.

27.2.1.2 Classification of Herbicides

Herbicides are grouped into five classificastions namely classification based on translocation, time of application, method of application, specificity, and site of actions as discussed below (Fig. 27.1):

Table 27.1 Types of herbicides

S/N	Type	Example
1	Contact herbicides	Diclofop, dinoseb, diquat, paraquat, treevix, gramoxone, oxyfluorfen
2	Systemic herbicides	Triazolophyrimidines, glyphosate, atrazine, 2,4-D dicamba, imazaquin sethoxydim, simazine, imidazolinones, sulfonylamino carbonyl triazolinones

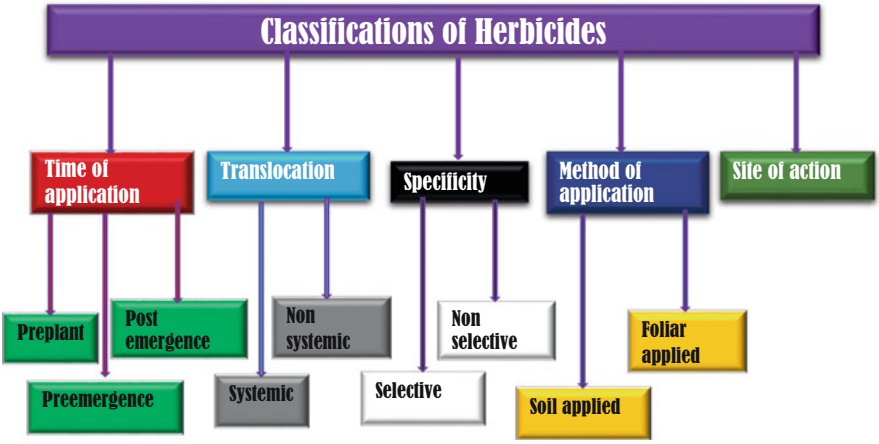

Fig. 27.1 Classification of herbicides

27.2.1.2.1 Classification Based on Translocation

Systemic/Translocated

Along with water, nutrients, and other substances, these herbicides are widely transported throughout the plant's vascular system from the point of absorption to the areas of action. Perennial weeds respond better to systemic herbicides than to contact herbicides. Systemic herbicides take longer (days or weeks) to destroy weeds than contact herbicides, which work quickly. Systemic herbicides that are non-selective include glufosinate and glyphosate. Examples of selective systemic herbicides are 2,4-D and dicamba.

Non-systemic/Contact

These herbicides only destroy the plant tissue that comes into touch with them. These do not move throughout the plant. For an effective application, uniform spray coverage and particle size are crucial. Perennial plants, which may regrow through rhizomes, roots, or tubers, are less successful with them. Contact herbicide must be used repeatedly to prevent the regeneration of subsurface plant components. These herbicides have a rather quick action, for instance, contact herbicides like bentazon and bromoxynil.

Classification Based on Time of Application

Pre-plant

Non-selective pre-plant herbicides (e.g. paraquat, glyphosate) are sprayed on the ground before planting and manually absorbed into the soil. Weeds are killed by herbicides as they spread across the herbicide-treated area. Before sowing the

pasture, volatile herbicides must be absorbed into the soil. Tomatoes, maize, soybeans, and strawberries are examples of crops that are cultivated on soil that has been pre-treated with a herbicide. The use of soil fumigants like dazomet and metam-sodium as pre-plant herbicides is common.

Pre-emergence

Herbicides are administered before the emergence of weed seedlings through the soil surface. Herbicides don't stop weeds from sprouting, but they do kill them as they spread over the herbicide-treated area by interfering with the seedling's ability to divide its cells. Two pre-emergence herbicides are dithopyr and pendimethalin. Pre-herbicides do not inhibit weeds that have already developed before application or activation because the treatment does not reach their main growth site.

Post-emergence

These herbicides are used to suppress weeds after the seedlings have broken the soil surface and often need many administrations to be effective. They might be systemic or contact, foliar or root absorbed, selective or non-selective. Herbicides in liquid form are more efficient than those in granular form. These herbicides should not be used while it's raining since the risk of them washing into the ground renders them useless. 2,4-D is a post-emergence herbicide that is selective, systemic, and foliar-absorbed.

Classification Based on Method of Application

Soil Applied

Herbicides used as pre-plant or pre-emergence treatments are often absorbed by the root or shoot of emerging seedlings. The efficiency of soil-applied herbicides depends on several variables. Herbicides are absorbed by weeds via passive and active mechanisms. Herbicide availability for weed absorption is often decreased by adsorption to soil colloids or organic debris. Herbicides must be placed in the proper layer of soil, which might be done manually or by rainfall. On the soil's surface, herbicides go through some processes that lessen their availability. Herbicide availability is often decreased by processes like photolysis and volatilisation. Many herbicides sprayed on the soil soak into plant shoots while the plants are still underground, killing or harming them. Herbicides used in the soil include thiocarbamates (such as EPTC) and dinitroanilines (such as trifluralin).

Foliar Applied

These are administered to the area of the plant that is above ground, and exposed tissues absorb them. These are often post-emergence herbicides, and they may either spread throughout the plant (systematically) or stay at a single location (contact).

Herbicide absorption and activity are influenced by plant barriers such as cuticle, waxes, cell walls, etc. The herbicides glyphosate, 2,4-D, and dicamba are sprayed on the leaves.

27.2.1.2.2 Classification Based on Specificity

Selective Herbicides

They may repress or regulate certain plants without having an impact on the development of other plant species. Selectivity across plant species may result via translocation, differential absorption, physical (morphological), or physiological differences. While 2,4-D, mecoprop, and dicamba effectively eradicate many broadleaf weeds, turfgrasses are unaffected.

Non-selective Herbicides

These herbicides destroy any plant material they come into touch with and do not just operate against certain plant species. Industrial areas, dumping grounds, railroads, and railroad embankments are all cleared using them. Non-selective herbicides include glyphosate, paraquat, and glufosinate.

27.2.1.2.3 Classification Based on Site of Action

Because herbicides belonging to the same site of action class often exhibit comparable symptoms on vulnerable plants, herbicides are frequently categorised according to their site of action. Herbicide resistance management is more easily and effectively managed when classification is based on the site of the herbicide's action.

Retzinger and Mallory-Smith founded the Weed Science Society of America. They suggested classifying herbicides based on their sites of action in the hopes that it would aid in the management of herbicide resistance. Each class was assigned a group number in order to distinguish amongst herbicides with the same site of action. Additionally, the International Herbicide Resistance Action Committee (HRAC) released a letter-based categorisation scheme for each category (Schmidt 2018). The categorisation was revised by Mallory-Smith and Retzinger (2013), who additionally included a few herbicides that were mentioned in the Weed Science Society of America's 2002 Herbicide Handbook but were not offered in North America. The necessary adjustments were made to bring this classification into alignment with the HRAC-published classification.

27.2.2 Fertilisers

The definition of "fertiliser" may be found in Act No. 156/1998 Coll. Fertilisers are thus necessary and administered to replace nutrients depleted from the soil by crop harvest and to supplement extra nutrients to increase crop output (Sharma and Chetani 2017). For the world's expanding population to produce wholesome food, plant nutrients are crucial. Therefore, plant nutrients are essential to sustainable agriculture. The sort of fertilisers used to augment the vital plant nutrients is a major factor in increased crop output (Usman et al. 2015). Because of differences in the nature and function of the nutrients produced by inorganic, organic, and biofertilisers, these three types of fertilisers as shown in Table 27.2 have their own set of advantages and disadvantages when it comes to crop growth and soil fertility. In order to provide both an enhanced and protected environment, it is necessary to establish and evaluate a balanced fertilisation strategy that involves the use of chemical, organic, and/or biofertilisers.

27.2.2.1 Fertilisers Classification

There are many different methods to categorise fertilisers, including the amount of nutritional components present, the kind of necessary nutrient present, etc. Heinz-Ulrich (2013) (Fig. 27.2).

Table 27.2 Types of fertilisers

S/N	Type	Examples
1	Organic fertiliser	ID grow, boost Xtra, Aleshinloye Asejere, neem, super Gro
2	Inorganic fertiliser	
a	Nitrogenous fertiliser	Sodium nitrate, ammonium sulphate, ammonium nitrate, ammonium sulphate nitrate, ammonium chloride, urea, calcium ammonium nitrate
b	Phosphate fertilisers	Single superphosphate, triple superphosphate, etc
c	Potassium Fertilisers	Muriate of potash, sulphate of potash
d	Compound Fertilisers	Amorphous
e	Complete Fertilisers	NPK fertilisers
3	Biofertilisers	Acetobacter, rhizobium

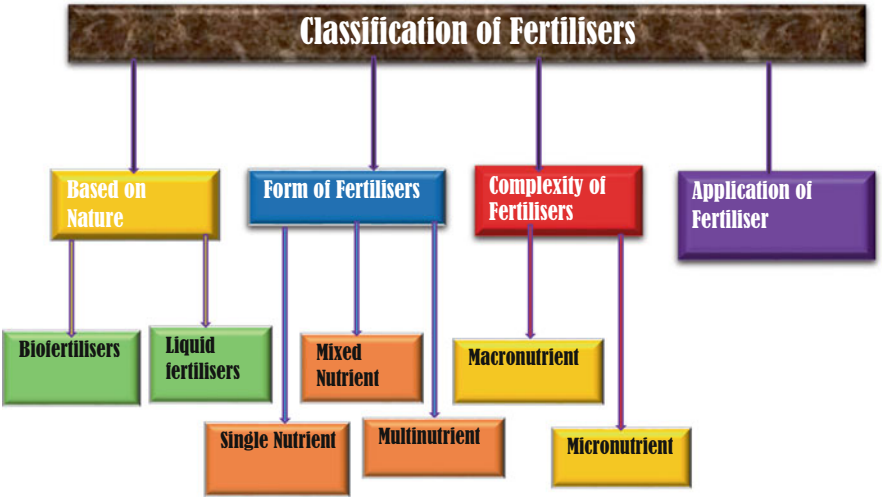

Fig. 27.2 Classification of fertilisers

27.2.2.1.1 Based on Nature

Synthetic fertilisers: These include artificially produced fertilisers, such as CO(NH2) 2 (Urea), which contains 45–46% nitrogen, and chile saltpetre, which has 15% nitrogen.

Fertilisers made from living or extinct organisms are known as organic fertilisers. Animal waste, agricultural plant waste, compost, and treated sewage sludge are a few examples. Animal sources can also include byproducts from animal slaughter, such as blood meal and bone meal, in addition to manures.

Biofertilisers: A biofertiliser is described as a product that includes live microorganisms that "exercise direct or indirect positive influence on plant development and crop output via multiple mechanisms" by Fuentes-Ramirez and Caballero-Mellado in 2005. Examples of solid fertilisers include crystals (ammonium sulphate), briquettes, powder (single superphosphate), granules (Holland granules), supergranules (urea supergranules), and prills (diammonium phosphate, urea, and superphosphate), among others (urea briquettes).

Liquid: Liquid fertilisers are administered directly or with irrigation water. The ease of handling, reduced labour demand, and potential for combination with herbicides have increased farmers' acceptance of liquid fertilisers.

27.2.2.1.2 Based on the Form of Fertiliser

Fertiliser that simply provides one basic plant nutrient, such as nitrogen, phosphorus, or potassium, is known as a single nutrient or straight fertiliser. For instance, potassium chloride, potassium sulphate, ammonium sulphate, and urea.

Binary and NPK fertilisers are examples of multinutrient or complex fertilisers. They provide two or three essential plant nutrients, two of which are combined chemically. Typically, these fertilisers are made in granular form. DAP, nitrophosphates, and ammonium phosphate, for instance.

Fertilisers that have been physically combined to combine two or three essential plant nutrients are known as mixed fertilisers.

27.2.2.1.3 Based on the Complexity of Fertilisers

Fertiliser with macronutrients: Contains one or two macronutrients that are necessary. Fertiliser with one or two micronutrients is known as micronutrient fertiliser.

27.2.2.1.4 Based on the Application of Fertiliser

Foliar fertilisation High value crops' leaves or fruits are directly fertilised with water-soluble straight nitrogen.

Controlled and slow-release fertilisers contain a plant nutrient in a way that either a) delays its availability for plant absorption and utilisation after application or b) is accessible to the plant for a substantial period of time longer than a reference fertiliser. Trade terminology for microbially degraded N products like UFs (Urea-Formaldehydes) and coated or encapsulated products is "slow-release fertilisers" and "controlled-release fertilisers," respectively. Fertilisers that include nutrients that are readily absorbed by plants include ammonium nitrate or urea, ammonium phosphate, and potassium chloride.

Fertilisers with a nitrogen basis and specific compounds to increase their effectiveness: A nitrification inhibitor prevents ammonia from being converted to nitrate, which is more prone to leaching. For instance, 1-carbamoyl-3-methylpyrazole (CMP), 3, 4-Dimethylpyrazole phosphate (DMPP) and nitrapyrin (2-chloro-6-trichloromethylpyridine). The hydrolytic conversion of urea into ammonia, which is vulnerable to both evaporation and nitrification, is slowed down by a urease inhibitor. For instance, urea ammonium nitrate (UAN).

27.3 Roles of Some Common Chemicals Used in Agriculture

27.3.1 Herbicides in Soils

Triketones, a relatively new class of herbicides from the family of triketones, are advised in European Union nations as an alternative to atrazine. They are post-emergence herbicides that are specific to maize. Leptospermone

(2,2,4,4-tetramethyl-6-(3-methylbutanoyl) cyclohexane-1,3,5-trione), a naturally occurring phytotoxin of the Californian bottlebrush plant, is the chemical source of triketones (Callistemon citrinus). They were created to reduce unfavourable environmental consequences. Although both the parent and produced byproducts of pesticide degradation may be hazardous (neurotoxic, endocrine disrupting) to non-target animals including algae, fish, invertebrates, etc. further research into these processes is of great interest. Triketone biodegradation has been extensively explored (Chaabane et al. 2018).

However, in natural settings, the breakdown of organic pollutants is the result of a number of processes, the most important of which are photochemical reactions involving sunlight (Chaabane et al. 2018). Sulcotrione (SUL;2-[2-chloro4-(methylsulfonyl)benzoyl]-1,3-cyclohexanedione), tembotrione (TEMB; 2-[2-chloro-4-(methylsulfonyl)-3-) and mesotrione (MES; 2-(4-mesyl-2-nitrobenzoyl)-1,3-cyclohexanedione), The triketone group's MES was the second-most popular herbicide sold worldwide in 2010 (Cropnosis Agrochemical Database 2010). Triketones are mostly employed in the production of maize as pre- and post-emergence herbicides. The anionic form of triketone herbicides exists at neutral or alkaline pH in molecular form at low pH and is present in all triketone herbicides as weak acids. The second form is more resistant to the processes of hydrolysis and photolysis.

MES breakdown products have been found in soils: 2-amino-4-methylsulfonylbenzoic acid (AMBA) and 4-methylsulfonyl-2-nitrobenzoic acid (MNBA), which is converted to AMBA. AMBA is more hazardous than the parent substance (Bonnet et al. 2018). SUL degrades in soil and water through two distinct mechanisms, claim Chaabane et al. (2017, 2018). Under certain circumstances (soil pH below 6.6), it degrades into 3-cyclohexanedione (CHD) and 2-chloro-4-mesyl benzoic acid (CMBA), as well as a derivative of phenylheptanoic acid (PHA). TEMB breaks down into a variety of substances depending on the environment (pH, presence of microorganism, sunlight, OC content). This herbicide's primary breakdown product, 2-chloro-4-mesyl-3-[(2,2, 2-trifluoroethoxy)methyl]benzoyl, is one of these. 1,3-dihydroxy-4,6-cyclohexane (TEMB MET) (Calvayrac et al. 2013). Despite the fact that triketones have been the subject of several investigations, the environmental stability of their breakdown products has not yet been adequately assessed. A non-renewable resource that is essential to both human endeavours and ecological sustainability is soil. However, the ability of soil to carry out its wide array of essential tasks may be diminished, mostly as a result of chemical pollution by pesticides (Mamy et al. 2011). Several research described how pesticides changed on the clay or soil surface. It is challenging to compare results and determine the stability of triketones and their degradation products in soils because studies on the transformation of triketone in soils have been conducted, but they have been conducted on individual compounds and/or under different experimental conditions (Chaabane et al. 2018).

27.3.2 Roles of Fertiliser in Agriculture

The main goal of applying fertiliser to soil is to increase the soil's nutritional status and quality by supplying it with the nutrients that it lacks. For crop plants to sustain their normal physiological function, the cell needs potassium, phosphorus, and nitrogen. In a similar vein, Mani (2002) claims that an overabundance of nitrogen leads to delayed maturity and poor leaf quality, whereas a deficiency in nitrogen leads to poor development and sluggish growth. Fertilisers are given to the soil to enhance its physical, biological, and chemical qualities since they contain all the nutrients plants need to flourish. Friability, porosity, and absorption of soil are examples of physical properties. The microorganisms that live in the soil have biological characteristics. The chemical characteristics are influenced by the pH (acidity level) of the soil, and the nutrients that are available to the plants. According to past reports, farmers utilize both organic and artificial fertilisers to improve production and maintain soil productivity (Chukwu et al. 2012). Several organic resources, including farm yard manure, cow dung, and bird droppings may be used as soil supplements to boost crop output (Asadu and Unagwu 2012). Fertilisers are thus necessary and administered to replace nutrients depleted from the soil by crop harvest and to supplement extra nutrients to increase crop output (Asadu and Unagwu 2012).

27.4 Effects of Common Chemicals Used in Agriculture

27.4.1 Effects of Herbicides on Soil Microorganisms

Microbial population in soil is being used as a measure of agricultural success. Due to their crucial involvement in the breakdown of herbicides, soil microorganisms are a key link in the connections between soil, plants, herbicides, animals, and humans (Raj and Syriac 2017). Application of herbicides alters the population of soil microbes significantly in both quantitative and qualitative parameters (Saeki and Toyota 2004; Raj and Syriac 2017).

An ideal pesticide, including a herbicide, must have the capacity to both operate on the pest it is intended to control and fast metabolise into non-toxic compounds (Stanley et al. 2013). Quantitative and qualitative alterations in the growth (stimulatory or depressive) and enzymatic activity of soil microbes may result after early-stage herbicide application, depending on the phytotoxic nature of the herbicide (type and concentration), microbial species, and environmental circumstances (Latha and Gopal 2010). Furthermore, these unintended effects on soil microorganisms may impair the efficiency of important soil processes including methane oxidation and organic matter (OM) breakdown (Sebiomo et al. 2011). It is crucial to remember that using herbicides often decreases the number of microorganisms like bacteria, fungus, actinomycetes, and protozoa, disturbing the ecological balance

between harmful and helpful species in the soil and making disease-causing organisms a problem (Kalia and Gupta 2004). One of the potential explanations of the drop in rice crop yield has been identified as a shift in the soil microbiota (Reichardt et al. 1998).

27.4.2 Effects of Herbicide on Soil Functions

Both the soil microorganism and the target organisms are impacted by the use of herbicides. The execution of crucial soil processes is often negatively impacted by these non-target effects on soil microorganisms. Disruption of the metabolic processes taking place in the soil is one of the likely negative effects of using herbicides. In reality, these herbicides often slow down biochemical processes by interfering with the enzymatic activity of the soil and the development of microorganisms (Maheswari and Ramesh 2019). The cycle of nitrogen, sulphur, and phosphorus in the soil as well as the breakdown of organic wastes are both greatly influenced by the population of soil microbes (Nielsen and Winding 2002). Any changes to the population or activity of soil microorganisms upset the biological balance in the soil, which may hurt soil fertility.

Herbicides applied to soil have harmful effects on the microbial community, which has led to decreased microbial biomass, soil heterotrophic respiration, and activity of OM degrading and nutrient-cycling microorganisms (Rose et al. 2016). An increase in the microbial community with the ability to use the herbicides as a carbon (C) source may be the cause of the rise in soil dehydrogenase (DH) activity in herbicide-applied soil after 7th day to 28th day. An increase in soil microbial activity, such as respiration and dehydrogenase activity, would result after the application of atrazine at a rate higher than 100 mg/kg (Moreno et al. 2007). Low doses of 2,4-D (0.5 mg/kg) had no effects on microbial respiration, while larger doses (5 mg/kg) had momentary impacts on hydrolase activity inhibition and short-term, or 24 day, stimulation of DH activity (Rose et al. 2016).

In conclusion, the use of different herbicides impacts a variety of biological processes in the soil, including respiration, C and N mineralisation, OM breakdown, enzyme activity, and nutrient cycling. A variety of variables, including the pace and timing of herbicide application and the agro-climatic conditions, affect the impact's size and direction (includes soil properties, temperature, and moisture). To determine the exact effect of the herbicide on soil biological processes and the mechanisms behind them, further study on different herbicidal reactions under varying situations is really needed.

27.4.3 *Effects of Herbicides on Vegetation*

Herbicides used on surrounding crop fields may provide a considerable ecotoxicological danger to plant populations in field margins, fallow fields, and other semi-natural habitats of agricultural landscapes (Egan et al. 2014). Field margins, fallow fields, and other semi-natural habitats are often the only places where wild plant species may still be found in agricultural landscapes. These places also contain a variety of plant communities that support pollinators, predators, and beneficial arthropods (Schmitz et al. 2014a, b).

Studies have shown that herbicides negatively impact plant communities, even at low doses, producing a loss in forb cover and a reduction in the blooming of important species (Egan et al. 2014), as well as a decrease in the frequencies of certain species (Schmitz et al. 2014a, b). Other research, however, contends that the variety of plant communities in agricultural settings may not be diminished by the use of herbicides (Leguizamón et al. 2012; Ahrens and Auer 2012).

Atrazine and tribenuron-methyl changed the species composition and decreased the variety of the plant communities in the fallow field in no more than three years, according to Yue et al. (2020). It was partially caused by the plants' species-specific susceptibility to these particular herbicides (Boutin et al. 2012). Due to their varied chemical characteristics, weeding strategies, and weed control goals, atrazine and tribenuron-methyl had minimal impact on perennial plants, whereas tribenuron-methyl had less impact on monocotyledons (Arntz et al. 1998; Tang et al. 2014). One of the key elements influencing the variety of weed communities was the kind of herbicide used (Leguizamón et al. 2012; Rassam et al. 2011). Additionally, community features are connected to how plant communities react to herbicides (Ortega and Pearson 2011). A gradient in plant strategies was also seen in the succession of the vegetation with fallow age (Egan et al. 2014). Early fallow communities are often dominated by opportunistic ruderal species that develop quickly and have an annual life cycle (Egan et al. 2014). Annuals were destroyed or impeded by the herbicides, especially atrazine, which may be one of the explanations for why perennials predominated in the herbicide-treated plots while annuals were more common in the blank control plots.

By lowering the number of species in the fallow area, the herbicides affected the composition of plant species overall and decreased the variety of plant communities. Because some species are known to respond favourably to disturbances, species richness may not always be the best indicator of healthy non-crop habitats in nearby farmlands (Fried et al. 2018). Nevertheless, changes in the number of species will unavoidably impact the plant interactions in a plant community.

Although herbicides may not have a significant short-term impact on the functional composition of plant communities, their cumulative long-term impacts on the functional composition and structure of plant communities in agricultural ecosystems must be carefully considered (Pellissier et al. 2014).

27.4.4 Deleterious Effects of Chemical Fertilisers

When agricultural plants are harvested, the amount of nutrients in the soil decreases over time. These nutrients are then restored by fertiliser application or natural decomposition. As a result, fertiliser is a crucial part of contemporary agriculture. However, even though chemical fertilisers are a major factor in the world's ability to produce enough food for everyone, their excessive use is posing serious problems for both the present and the next generation, including air, water, and soil pollution, degraded lands, depleted soils, and increased greenhouse gas emissions.

These artificial fertilisers are not only endangering our environment but also endangering people, animals, and microbiological life. It is past time for everyone to become aware of the negative effects of using excessive amounts of chemical fertilisers and to take steps to replace them with other organic amendments, such as organic manures, which not only provide the plants with vital nutrients but also maintain the soil's health for future crops. There are a tonne of other technologies that are being developed, such as slow-release or controlled-release fertilisers, prilled or granulated fertiliser, nitrification inhibitors, nano-fertiliser, etc. All of these are promising solutions that we can use to overcome these significant obstacles and preserve the ecosystem as well as our environment. Let's learn about the many risks associated with using chemical fertilisers excessively to increase crop productivity.

27.4.5 Effects of Chemical Fertiliser on Soil Pollution

The natural framework and environment for plant development is the soil. The soil serves as a home for soil organisms, a method for recycling nutrients, and a host of other ecosystem functions. Overuse of chemical fertilisers may result in soil acidification and soil crust, which lowers the amount of organic matter, humus, and beneficial organisms in the soil, stunts plant development, alters the pH of the soil, increases pests, and may even cause greenhouse gases to be released. The soil's acidity reduces the amount of phosphate that crops can absorb, raises the concentration of harmful ions in the soil, and prevents crop development (Okereke et al. 2019; Cooke 2012). The soil's capacity to hold nutrients is diminished when humus depletes. The climate is harmed by greenhouse gases produced by too much nitrogen fertiliser. Large volumes of nitrogen sprayed to fields over time disturbs the equilibrium between the three macronutrients, N, P, and K, leading to a shortage of micronutrients and damaging the topsoil, which lowers crop yields. In comparison to clay soils, sandy soils are far more susceptible to soil acidification.

The impacts of excessive chemical fertilisation might be masked by clay soils. Chemical fertiliser applications made repeatedly may cause the soil to become toxically contaminated with heavy metals including uranium, cadmium, and arsenic. These harmful heavy metals accumulate in food grains, fruits, and vegetables in addition to polluting the land (Okereke et al. 2020; Osawaru et al. 2013a, b;

Nwizugbo et al. 2023). For instance, fertilisers like triple superphosphate include trace metals like cadmium and arsenic that build up in plants and may affect human health via food chains. Chemical fertilisers have significant and lasting negative impacts on soil (Sonmez and Sonmez 2017). Application of fertiliser without following the advice of soil testing may have effects such as soil deterioration, nutrient imbalance, loss of soil structure, and an increase in bulk density. Overuse of fertilisers results in the formation, accumulation, and concentration of mineral salts of fertilisers, which over time causes soil compaction and degradation.

27.5 Impacts of Common Chemicals Used in Agriculture on Soil Microorganisms

27.5.1 Impacts of Herbicides on Soil Microorganisms

Depending on the kind of herbicidal chemicals used, herbicides reduce the overall microbial population after 7–30 days of treatment (Milosevic and Govedarica 2002). In addition, they indirectly reduce microbial biodiversity by changing their physiology or metabolic pathways (Kremer and Means 2009). This in turn impacts the quantity of plant growth regulators (gibberellins production, transportation of Indoleacetic Acid (IAA), ethylene concentration, etc.) as well as soil enzymatic activity, cellular membrane composition, protein biosynthesis, and other factors. Numerous delicate bacteria have reportedly perished as a consequence of the overuse and greater concentrations of herbicides (Milosevic and Govedarica 2002).

The detrimental effects of applied chemical herbicides on soil microbial diversity depend on soil factors like texture, vegetation, tillage system, and organic matter as well as agrochemicals' degradability, adsorption and desorption, bioavailability, bioactivity, persistence, concentration, and toxicity (Yadav et al. 2017). When compared to a no-till (NT) regime, conventional tillage causes a greater drop in soil microbial functionaries. After 12 days of application of the herbicide fomesafen and mixes of fluazifop-butyl + iifomesafen, the soil's microbial biomass carbon (MBC) and mycorrhizal colonisation decline under the conventional till (CT) system (Santos et al. 2006). As is the case with butachlor when used in conjunction with cadmium, certain microbial populations are more susceptible to the interaction impact of herbicides with other substances than the usage of a single herbicide.

Other herbicides may inhibit the actions of soil microorganisms when used with inorganic fertilisers and heavy metals (Chen and Dixon 2007; Datta et al. 2017; Mishra and Wimmer 2017; Mishra and Ekielski 2019). Herbicides undergo physical and metabolic changes after application, creating a number of secondary metabolites that are more harmful or persistent to microbial populations that aren't the intended targets. The impact of 2,4-D and its metabolites on Burkholderiacepacia, a genus of gram-negative bacteria, serves as an illustration of this (Smith and Beadle 2008). Along with the active component, such as surfactant and solvent, the herbicidal

effect also relies on the formulation type. When polyoxyethylene amine is added to glyphosate, the herbicide becomes more hazardous to bacteria than glyphosate acid alone (Tsui and Chu 2003).

27.5.2 Impacts of Fertilisers on Microorganisms

Without the use of mineral fertilisers, crop production is nearly impossible nowadays. In agricultural systems, fertilisers may boost production and, as a consequence, product quality (Savci 2012). However, excessive fertiliser usage, which is a common occurrence in contemporary intensive agriculture, often has negative impacts on both the environment and human health. Furthermore, both organic and inorganic fertilisers have the potential to have a major impact on the structure and operation of the soil microbiota, which is directly related to soil fertility and health.

Numerous research have been carried out to determine the impact of various fertiliser kinds on soil microbiology. It has long been known that organic matter supplied to the soil system affects the behaviour of soil microorganisms (Swift et al. 1979). Therefore, it was hypothesised that soil modified with chicken dung would have much higher bacterial density, CO2 evolution, and enzymatic activity than untreated soil (Bhoi and Mishra 2012).

However, a great deal of research indicates that mineral fertilisers have a detrimental impact on soil microbes. According to a study of the literature by Allison and Martiny (2008), microbial communities are responsive to nitrogen (N), phosphorous (P), and potassium (K) fertilisers, with up to 84% of the 38 papers reporting this. On the basis of unmanaged ecosystems, some meta-analysis (Treseder 2008) discovered that N treatment may reduce soil microbiology. However, it is anticipated that the agricultural land's microorganisms would respond differently from those in natural ecosystems. Due to extensive fertiliser application throughout the year, agricultural land has a nitrogen concentration that is higher than the quantity of nitrogen in a natural environment. High N fertiliser application rates have the ability to temporarily raise osmotic potential levels; also, certain N form quantities have the potential to be hazardous (Omar and Ismail 1999). Additionally, it is known that increasing the application of N fertilisers may modify the pH of agricultural soils, which has a significant impact on the microbial composition (Geisseler and Scow 2014).

27.6 Impacts of Common Chemicals Used in Agriculture on Vegetation

27.6.1 Impacts of Herbicides on Vegetation

Atrazine and tribenuron-methyl, which both decreased the number of plant species, according to Yue et al. (2020), did not substantially alter the functional content of the plant communities after 3 years. According to prior research, fertiliser drift seemed to have a much greater impact on the plant trait composition in field margin strips than did herbicide drift (Fried et al. 2018); however, over the course of 11 years, a significant interaction between herbicides and other agrochemicals changed the functional structure of communities (Pellissier et al. 2014). Studies on the impacts of herbicides on plant functional groups in agroecosystems are few, despite the fact that plant functional trait analysis might more accurately indicate the contribution of non-food plant resources to food production and biodiversity in agroecosystems (Balzan et al. 2016).

Although species-specific responses were inconsistent, sublethal herbicides have been found to have an impact on the germination and seedling development of the F1 generation of plants. Sublethal herbicides' impact on plants may alter how the plant community develops, which may alter the variety and species makeup of the plant community. Due to the fact that herbicide drift and runoff from sprayed fields into nearby non-target regions often result in low concentrations or sublethal doses of herbicides in agricultural landscapes, greater focus should be placed on preventing and controlling these ecological concerns (Boutin et al. 2012; Schmolke et al. 2018). To minimise ecological concerns, a certain distance between farmlands and non-target regions may be maintained (Schmitz et al. 2014a, b).

27.6.2 Impacts of Chemical Fertilisers on Vegetation

The world's agricultural systems use a lot of chemicals, such as fertilisers, pesticides, and herbicides, to increase production per unit area, but using more of these chemicals and fertilisers than is ideal or recommended causes a number of issues, such as soil pollution, decreased input efficiency, decreased food quality, resistance development in various weeds, diseases, insects, soil degradation, a lack of micronutrients in the soil, and toxicity to various beneficial organisms. Despite all of these issues, it is difficult to provide the world's expanding population with food. Therefore, it is important to develop agricultural products that are high in nutrition and free of chemicals for human and animal consumption without harming the environment. As a result, focus should be placed on producing food that is both high in quality and quantity.

Without a doubt, fertiliser application helps plants by supplying them with the nutrients they need. However, it also offers a number of advantages over organic

fertiliser, including being a more affordable source of nutrients, having a greater nutritional content and being instantly available. There is a tonne of proof that inorganic fertilisers may considerably increase crop output. Fertilisers increase soil fertility so that crop output is no longer constrained by insufficient levels of plant nutrients. Despite these advantages, fertiliser has a number of harmful environmental impacts due to its rising usage and decreased nutrient use efficiency. Therefore, integrating intense cultivation with high nutrient use efficiency is the primary difficulty in intensive agricultural production systems.

27.7 Problems Associated with Current Approaches of Chemical Application for Agricultural Productivity

Agricultural chemicals have obviously been used, but their effects on the environment and people must be reduced and under control.

The following list includes some hazards or issues related to the use of nutritional additives for crop fish production and poultry enhancement:

1. Excessive chemical fertiliser usage from chemical run off via rain water may have a negative impact on surrounding water bodies and waterways. As a consequence, there is less oxygen in the water, which causes the aquatic system to hypertrophicate. The oxygen levels in the water body are depleted as a result of the live creatures present there, which might result in the death of the majority of aquatic species, including fish.
2. Excessive and repeated applications of nitrogenous fertiliser beyond the capacity of the crop can release greenhouse gases carbon dioxide and nitrous oxide into the atmosphere, contributing to global warming and unpredictable weather patterns.
3. Excessive use of chemical fertilisers may lead to a loss in organic matter in the soil, which can result in acidification of the soil and dangers to plant viability.
4. When chemical fertilisers are applied in an unbalanced ratio, they eat an essential portion of the soil's nutrients, lowering the quantity of minerals and vitamins in food products.

   The natural nutrients of the soil become unbalanced when excessive doses of fertilisers are added to it. Use of fertilisers with nitrogen diminishes system stability and results in soil acidity (Suman Patra et al. 2016).
5. The whole necessary nutrient required for plant development and production is seldom present in animal dung. Some methods of manure application commonly cause imbalances and nutrient buildup in soil that may be hazardous to the environment. Additionally, the mineralisation of compost and manures rely on intricate interactions between soil and environmental conditions that are difficult to forecast and often lead to decreased fertiliser efficacy.
6. Fish farming delivers soluble nutrients from fish feed, including nitrogen and phosphorus, into the marine ecosystem. These nutrients may boost the development of marine plants and algae (Gamal et al. 2008).

7. Some of the nitrate fertilisers that are applied to the soil are converted to nitrite. This is absorbed by the plant, particularly vegetables, or leached into the water body. It may be implicated in the creation of cancer-causing chemicals like nitrosamine and nitosamide if consumed in excess. Additionally, excess nitrate from manure or chemical fertiliser that has leached into the water presents a serious danger to unborn children and expectant mothers. Methenoglobinemia, a disease condition, results from this. a disease brought on by the blood's hemoglobin's capacity to carry oxygen (Olga 2014).
8. Numerous endogenous steroids, including their semi-synthetic and synthetic equivalents, have been created and given to animals in order to boost reproduction and promote animal development for food production. Some research papers mentioned their potential for causing cancer, genotoxicity, and interfering with the normal physiological processes of humans and animals. Additionally, it has been shown that areas where hormone-treated meat is eaten have the greatest incidence of hormone-related cancer, including cancer of the breast, ovary, prostate, testes, and colon.

27.7.1 Risks Associated with Herbicides

1. The environmental persistence of certain pesticides is said to be particularly high. As they move up the food chain, they can pose long-term risks. Humans are at the top of the food chain, especially breastfed infants. The majority of POPs and PTSs (Persistent Toxic Substances) are lypophilic chemicals with poor water solubility that are resistant to environmental degradation and build up in adipose tissue. The largest concentrations are seen in marine animals, but they bio-concentrate in fish, wildlife, and human tissues as well. POPs and PTSs may have negative endocrine and developmental impacts, particularly in children (WHO XE "World Health Organization (WHO)" 2008).
2. Many herbicides are known to be hazardous to humans, and some of them work by immobilising nutrients in the soil so that plants cannot absorb them. For instance, paraquat is known to injure tissue by triggering a redox process that results in the production of the dangerous super oxide free radicals. When exposed acutely, it kills by harming the lungs. It has a connection to Parkinson's disease as well.
3. They immobilise the vital minerals that plants need for growth, such as glyphosate, which studies have shown to create stable complexes with metals required for plant growth. Through the use of amino, carboxyl, and phosphonate groups, it forms compounds with transition metals (Danilla et al. 2012).

27.8 Management and Sustainability Approach

Interestingly, research on the detrimental effects of pesticides and fertilisers have been undertaken for more than a century, and several legislative measures and agrochemical-related occurrences have been recorded (Pandey and Singh 2004). The development of quick and accurate analytical methods has opened the door to a better knowledge of the threats that pesticides and fertilisers connected to soil and plants represent over the long term. Therefore, new legal measures are being updated or adjusted at a quick rate, indicating significant advances in smarter and more effective pest management. This is due to the ever-growing information on pesticide linked health and environmental hazards (Enserink et al. 2013). An efficient method for reducing the negative impacts of agricultural chemicals, particularly pesticides (herbicides), their applications, and their residues, is integrated management (Owen et al. 2015). Many of the most recent ecologically friendly strategies to combat the danger of herbicide and fertiliser contamination have put biological weed management at the forefront. In the talk below, some of the most important successful management techniques are outlined and others are shown in Fig. 27.3:

- Ensuring strict compliance of ecological and environmental legislations.
- At each region, an identification and protection of no-target plant species should be made.
- Strict monitoring of toxic remains in plant parts, animal-based food, and the environment.
- In terms of agrochemical usage Good Agricultural Practices (GAP) for each crop should be defined.
- Promotes an Integrated Pest Management (IPM) system among farmers.
- Standardizing Maximum Residual Limit (MRL) for each chemical used in agricultural practices.
- Detoxification and degradation of chemical residues in the environment.
- Emphasising and educating farmers about the occupational and consumer risks associated with the use of agro-chemicals.
- Government at all regions should underpin and organise infrastructure for registering pesticides and enforcing legislations (Fig. 27.3).

27.9 Conclusion

The goal of agricultural development is to feed and provide enough food and surplus to the growing human population while maintaining the biosphere's ecosystem and environment. In underdeveloped countries, agrochemicals and their application are seen as the solution for all agricultural difficulties. Agrochemicals and their derivatives are persistent in the soil for a long time, thereby posing substantial risks to the soil ecosystem and human health. The majority of them have a detrimental impact on the biochemical activities, variety, and activity of microorganisms. Additionally,

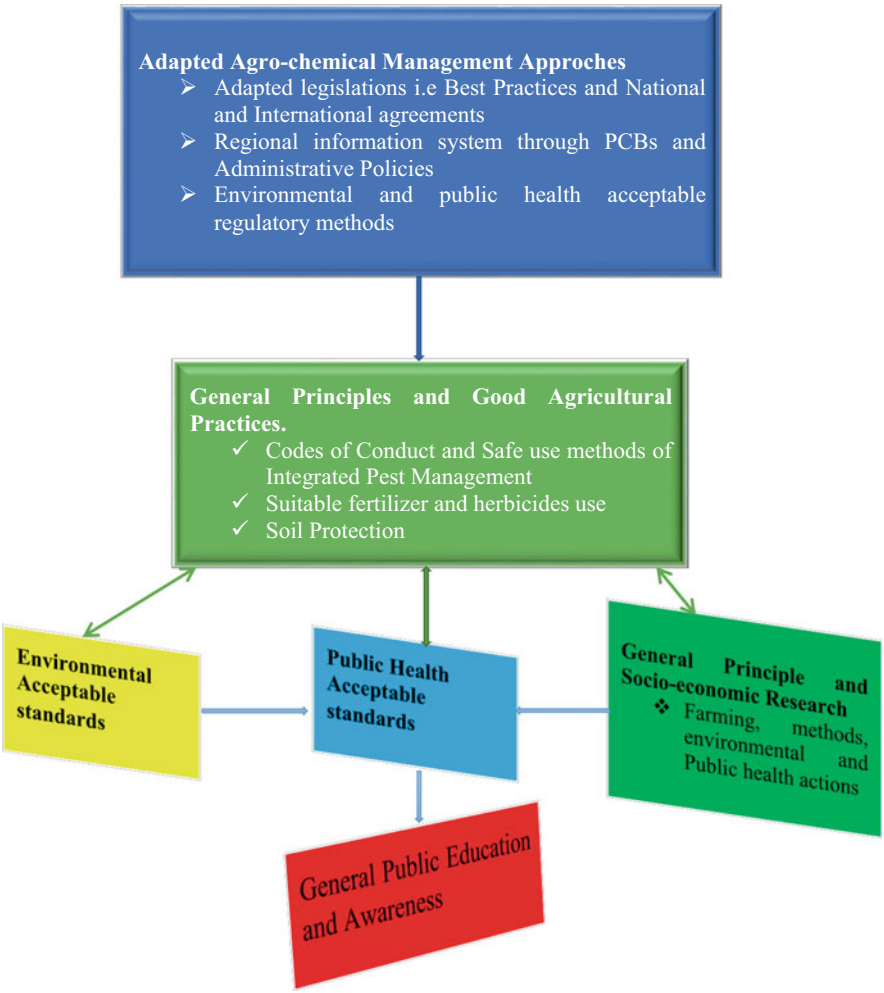
Adapted Agro-chemical Management Approches
Adapted legislations i.e Best Practices and National and International agreements
Regional information system through PCBs and Administrative Policies
Environmental and public health acceptable regulatory methods
General Principles and Good Agricultural Practices.
Codes of Conduct and Safe use methods of Integrated Pest Management
Suitable fertilizer and herbicides use
Soil Protection
Environmental Acceptable standards
Public Health Acceptable standards
General Principle and Socio-economic Research
Farming, methods, environmental and Public health actions
General Public Education and Awareness

Fig. 27.3 Sustainable management approaches of agrochemical use

they alter the soil's fertility, which has an immediate impact on crop output. Because the majority of negative effects are brought on by application dosages that are more than the recommended rates, careful and selective use of these agrochemicals is essential. For the purpose of minimising the negative impacts on people and the environment, it is essential to educate farmers, distributors, business leaders, politicians, and other stakeholders on the appropriate use of herbicides and fertilisers. Create monitoring practises and a database to track agricultural chemical contamination levels in crops and animal products. This will assist in resolving the issue of foreign markets rejecting our agricultural goods. Applying the proper amount of nutrients to the soil and animal meals. Create sensible regulations for the use of chemicals to improve agricultural products.

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